A Climatology of Erythemal Ultraviolet Radiation, 1979−1992

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1 Abstract

The distribution of erythemal (skin−reddening) ultraviolet radiation at the Earth's surface is derived from satellite−based observations of atmospheric ozone and cloud reflectivity. This climatology may be helpful in assessing the role of long−term environmental exposure to ultraviolet radiation, e.g., in epidemiological studies of skin cancer. Comparisons with ground−based measurements show agreement at the 10−20% level, except at high latitudes.

2 Methods

Total ozone and cloud/aerosol reflectivity at 380 nm were taken from the Total Ozone Mapping Spectrometer (Nimbus−7 TOMS, Level 3/V.7, [5]) from Jan. 1979 to Dec. 1992, at a geographical resolution of 1.25° longitude by 1.00° latitude. Total ozone was used as input to the Tropospheric Ultraviolet−Visible (TUV) model [3], the effect of clouds was considered in a second step [1]. Spectral irradiance $F(\lambda)$ at the Earth's surface was calculated every 30 minutes (1979−92) at 1 nm steps from 280 to 400 nm, using a 4−stream discrete ordinates method [7] with pseudo−spherical correction for improved accuracy at low sun [6]. Erythemally effective irradiance was calculated as

$$UV_{\mathrm{ery}} = \int B(\lambda)\, F(\lambda)\, d\lambda \qquad (1)$$

where $B(\lambda)$ is the CIE erythemal sensitivity function (action spectrum) [4].

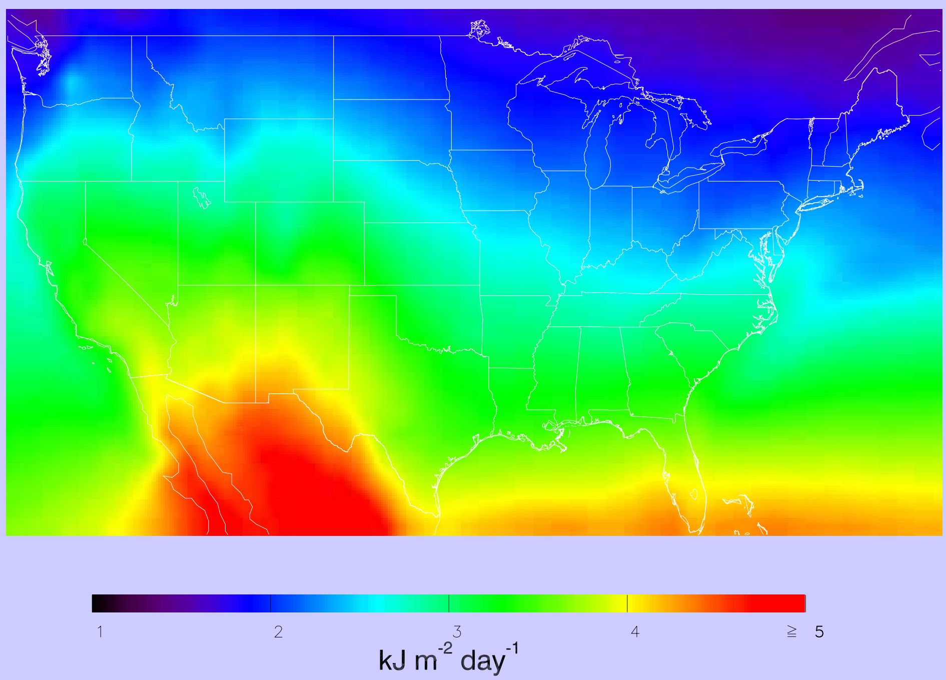

Figure 2: Daily erythemal UV doses averaged over 1979−92, United States.

3 Results and Discussion

Figure 1 shows the geographical distribution of daily UV_{ery} doses (top) and the corresponding cloudless sky values (bottom), averaged over the entire time period. As expected, highest values are generally seen in the tropics, up to ca. 7 kJ m^{-2} day^{-1} in the eastern Pacific and eastern Africa, while middle latitudes of both hemispheres show a general pole−ward decrease from about 5 to 1 kJ m^{-2} day^{-1}. Lo−cal highs are associated with higher elevations, smaller ozone columns, and infrequent cloudi−ness (e.g., Andes mountains, Tibet plateau, Mexico and southwestern US). A more detailed climatology for the contiguous United States is shown in Figure 2.

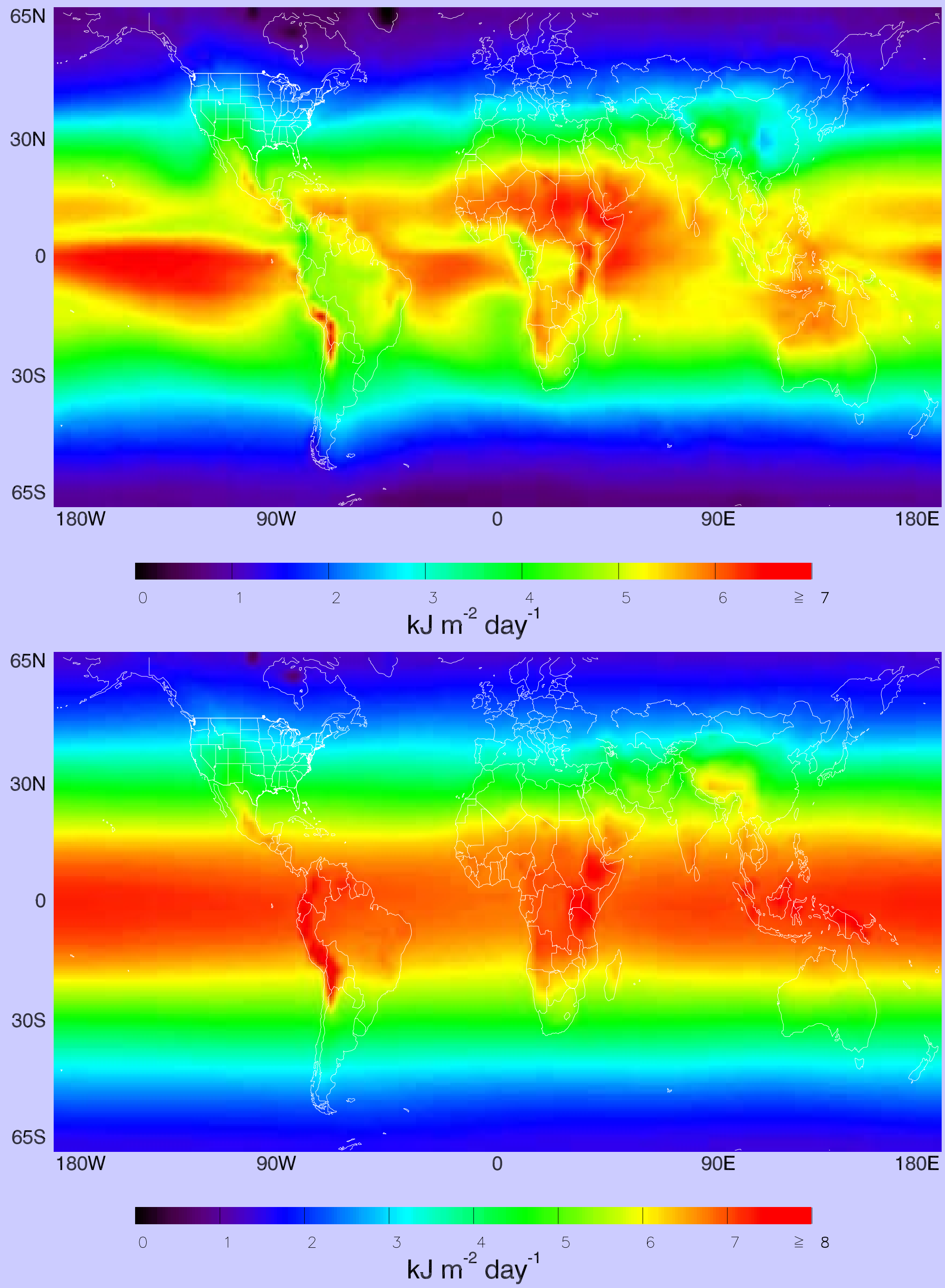

Figure 1: Daily erythemal UV doses averaged over 1979−92. (Top) Including clouds, (Bottom) cloudless sky.

Comparisons with ground−based measurements, as archived at the World Ozone and UV Data Center (WOUDC) [8], are shown in Figure 3, for annually averaged daily UV_{ery} doses. With the exception of Palmer station, satellite−derived annual averages tend to over−estimate measurements by ca. 10−20%, as also found by [2] for the Toronto measure−ments. These discrepancies remain under in−vestigation and may stem from both measure−ments (e.g., cosine error) and satellite−derived values (e.g., local pollution) [2]. The dis−agreement at Palmer station is a consequence of using TOMS−observed reflectivity to infer cloudiness, when in reality the high reflectivity may be due to snow and ice, thus leading to a significant underestimate of UV_{ery}.

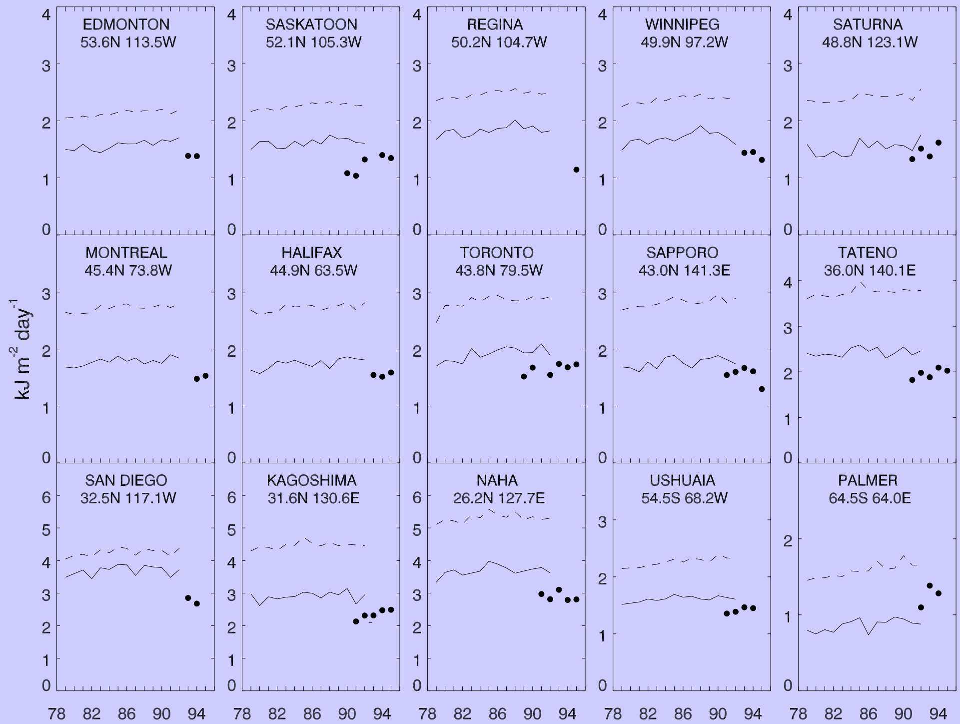

Figure 3: Annually averaged daily $UV_{\mathbf{ery}}$ doses; satellite−derived climatology and ground−based measurements. The dashed lines are cloudless−sky calculations.

This nearly−global UV climatology may be a valuable tool in the study of the consequences of UV exposure in the biosphere, for example in epidemiological studies of human skin cancer, and in the assessment of long−term UV stresses on terrestrial and aquatic ecosystems.

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